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## **TECHNICAL REVIEW OF THE PROPOSED WATER RECIRCULATION SCHEME OF THE NEW PROSPERITY GOLD-COPPER MINE PROJECT ON PREDICTED EFFECTS ON FISH AND FISH HABITAT OF THE FISH LAKE WATERSHED**

### **Context**

Taseko Mines Limited (the Proponent) proposes to develop and operate the New Prosperity Gold-Copper Mine Project 125 km to the southwest of Williams Lake, British Columbia (BC). The Project would involve the construction, operation, and closure of a large gold-copper mine which would take two years to build and would operate for 20 years. The main project components include an open pit mine, a 125 km power line, an onsite concentrator, a new 2 km access road and a tailings pond.

The proposed mine would be located within the Fish Creek watershed, which hosts several fish-bearing creeks and lakes, including Fish Lake and Little Fish Lake. The Fish Lake supports a population of rainbow trout estimated in 1997 to be 27,000 adult fish. The direct and indirect effects of the mine include an open pit mine immediately downstream of Fish Lake and the development of a tailings impoundment area in upper Fish Creek watershed that will cover Little Fish Lake and the headwaters of Fish Creek. The Proponent proposes to actively capture and pump the discharge from the outlet of Fish Lake to the remaining reaches of headwater streams to retain inflow to the lake. Upon mine closure and for approximately 50 years, it is planned to have water flow freely from the tailings impoundment to Fish Lake to the open pit lake and then downstream to Taseko River.

The New Prosperity Gold-Copper Mine Project is subject to an environmental assessment federal review panel. Fisheries and Oceans Canada (DFO) will be invited to attend the public hearings and present its views on the project to the Panel. Specifically, DFO will be asked to present a submission at the hearing related to DFO's mandate and expertise respecting the effects of the Project on fish and fish habitat, the mitigation and compensation measures, the conclusions reached by the Proponent, and the monitoring and follow-up programs. On June 12, 2013, DFO's Pacific Region Fisheries Protection Program requested that DFO Science Branch provide an evaluation of the Proponents Environmental Impact Statement (EIS) to assist in the development of DFO's submission to the New Prosperity Gold-Copper Mine Project Review Panel.

Based on the information contained in the September 2012 EIS, the supplemental information provided in March 2013 and June 2013, and supporting documentation provided historically by the Proponent, the objective of this Science Response is to assess whether the proposed re-circulated closed lake system of Fish Lake, and its tributaries, can feasibly provide the fish and fish habitat attributes described in the EIS, and whether the limitations and uncertainties associated with this recirculated system are accurately characterized.

This Science Response Report results from the Science Special Response Process conducted in June 2013.

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## Background

Fish Lake is a 112 ha, biologically-productive and shallow lake ecosystem located in the Fish Creek drainage of the Fraser plateau. As outlined in the Environmental Impact Statement (EIS) and subsequent supplementary submissions by the Proponent (see context), the proposed New Prosperity Mine will impact the catchment hydrology supplying Fish Lake, the hydrological and hydrochemical properties of its tributaries, as well as the limnological characteristics of the lake itself. The potential for the project to affect freshwater habitat and the persistence of a non-anadromous *Oncorhynchus mykiss* (rainbow trout) population harvested in both aboriginal and recreational fisheries is the subject of this assessment.

As outlined in the EIS, > 50% of the upstream catchment area for Fish Lake would be cut off from Fish Lake during the life of the mine. Discharge from the outlet of Fish Lake would be actively captured and pumped up to the remaining reaches of headwater streams to retain inflow to the lake. Specifically, this assessment will evaluate the potential for the recirculation of lake water to impact the trophic status and ecosystem structure and functioning of Fish Lake and the tributary streams and the implications for future fisheries productivity. The New Prosperity Mine EIS and associated documentation was reviewed with a focus on the predicted physical, chemical, and biological changes to the spawning and rearing ecosystem habitat components that sustain the Fish Lake rainbow trout monoculture.

Fisheries and Oceans Canada's Ecosystems Management Branch has deemed the aspects of fish survival and reproductive success related to contaminant loading and fish contaminant burdens to be the jurisdiction of Environment Canada. Therefore, any potential contaminant influences on lake productivity (i.e., food web impacts), although potentially important, have not been explicitly considered here.

The review is divided into two sections, the first considers the effects of the proposed project on the tributaries to Fish Lake, and the second the effects on the lake itself.

## Analysis and Response

### Fish Lake Tributaries

The New Prosperity proposal will reduce the amount of spawning and juvenile rearing habitat for Fish Lake rainbow trout. Most of that loss occurs as a result of the isolation of the outlet stream and the headwaters of upper Fish Creek, the largest inlet stream. Although the focus in the EIS is on spawning habitat (Taseko 2012, APPENDIX 2.7.2.4B-D; all references will be to this document unless otherwise indicated) evidence from studies of other stream dwelling populations of salmonids suggests that it is likely that the availability of habitat for age-0 and age-1 juveniles in the tributary streams is the limiting factor affecting recruitment to the adult population in the lake. Results from the 1997 fence studies (Taseko 2009, v5d009) clearly indicate the significance of both the inlet streams and especially the outlet stream as juvenile rearing habitats. Therefore, this review considers the effects of the proposed project on **both** spawning and rearing habitat.

Based on wetted area under late summer flows, the New Prosperity project is expected to reduce the total stream rearing area for juvenile fish by 60% (calculated from baseline data [Taseko 2012, Table 2.6.1.5-9] and projected wetted surface areas for Reach 8 and Trib#1, with flow augmentation and channel modification). This estimate is similar to the projected loss in spawning habitat, calculated at 63% (Calculated from Table 2 and 4). If it assumed that the reduction in wetted area will cause a proportional reduction in the production of age-1 fish that migrate to the lake, the lake population could be reduced by a corresponding amount. Based on

1997 estimates of the number of adult fish (~27 000), the post-project adult (age 4+) population is predicted to be in the range of 10 000 fish, which should be sufficient to avoid risks associated with small population size (Reed et al. 2003). The reduced number of fish recruiting to the lake will likely result in better fish growth and larger adults (Askey 2007). Increased growth can also increase survival of fish in the lake (Post et al. 1999), which may counteract some of the reduction in juvenile production.

After project development, the primary functions of the two tributary streams for a self-sustaining rainbow trout population will be to:

1. Provide an appropriate environment for the spawning of adult rainbow trout and successful incubation of eggs and alevins.
2. Provide an appropriate environment to produce sufficient age-1 rainbow trout recruits to the lake, including habitats for both summer and winter seasons.

To offset the loss of spawning and rearing habitat in the outlet stream, as well as the loss of the headwaters of upper Fish Creek and Tributary 1, the Proponent proposes to recirculate water from the lake to the upper limit of the remaining segments of these tributaries. Upon review, it is apparent there are significant risks with this scheme for the long-term viability of the functions of the streams and the productivity of the rainbow trout population that are not identified or not fully addressed in the documentation. These are listed in the sections below.

### Channel maintenance flows

It is well recognized that high flows are necessary to maintain stream function. In unregulated streams, high flow caused by spring freshet or rain events mobilizes the stream bed, removing accumulated fine sediment and organic debris. This maintains the quality of the bed for the incubation of salmonid eggs by restoring gravel permeability, and provides an appropriate substrate for the production of invertebrates that are preferred food items for young fish. Cover for young fish is also provided by the presence of unembedded stream bed materials. When high flow events are eliminated, stream bed quality can deteriorate quickly, greatly reducing its potential for fish production (Schmidt and Potyondy 2004). Hartman and Miles (2001) provide many examples of artificial spawning areas for rainbow trout that have deteriorated without high flows or other forms of maintenance. Similar experiences have been documented for other salmonid spawning areas (e.g., Pulg et al. 2013 and references therein). Movement and redistribution of bedload, and woody debris and the undercutting of stream banks during high flow events, also create important habitat structures for rearing juveniles. Freshet flows are also important for the maintenance of the riparian zone and off channel habitats. Elimination of high flows can also cause the encroachment of woody vegetation into the stream channel which can alter stream habitat conditions.

Beaver are present in the valley, and contribute to the creation of pool habitats and likely provide overwintering areas for juvenile trout in upper Fish Creek. Fish production in streams that support beaver is maintained by the balance between very high spring flows that breach dams and flush the accumulated sediments, and the activities of the beaver populations to restore them. In the absence of high flows, there is the potential for beaver dams to render both tributary streams unsuitable for fish production if access for spawners is blocked, and sediment deposition behind dams eliminates spawning habitats. High flows also interact with beaver dams to flood riparian areas and recharge shallow groundwater (Westbrook et al. 2006). This dynamic may be altered if peaks in the hydrograph are removed.

One estimate of the peak flow for upper Fish Creek is found in Figure 2.6.1.4B-4, where flow in early May 2007 was estimated at  $3.0 \text{ m}^3\text{s}^{-1}$  (unit discharge  $75 \text{ l/s/km}^2$ , watershed area  $39.8 \text{ km}^2$ ). It is unknown whether this flow was sufficient to provide channel maintenance function.



Apparently only one year of flow data is available, but the 2007 hydrology analysis suggests that 10 yr peak flows of 150-200 l/s/km<sup>2</sup> could occur (Taseko 2009 vD4011 Fig 4.8), corresponding to a peak instantaneous flow of 6-8 m<sup>3</sup>s<sup>-1</sup>. These flows are much higher than the maximum flows for upper Fish Creek (0.45 m<sup>3</sup>s<sup>-1</sup>) to be provided by the proposed water management system.

Bankfull discharge is sometimes used as a reference point for maintenance flows; using a regional hydrology approach from Western Montana (Lawlor 2004) based on watershed area, an estimate of 1.33 m<sup>3</sup>s<sup>-1</sup> is obtained for upper Fish Creek. Site-specific analysis should be conducted to evaluate the flows required to perform channel maintenance function.

In summary, there is a high risk that the absence of channel maintenance flows will result in the deterioration of the productivity of habitats in the inlet streams. Experience elsewhere suggests this can occur rapidly.

### Thermal regime

The predicted changes in stream water temperature resulting from recirculating water from the lake to the inlet stream are similar to those observed in releases below storage dams (Olden and Naiman 2009). The thermal inertia of the lake results in warmer flows in the fall and winter, and cooler in the spring and summer relative to baseline stream temperatures. Although the temperatures are often within the thermal tolerances of species, the altered thermal regime can have effects on stream fish that should be considered risks.

The analysis of the thermal regime appears to rely on stream temperatures observed at the lowest segment of upper Fish Creek, where the monitoring station and fish fence were located. There is potential for a gradient in water temperature along the length of the stream, especially in summer when flows are low and air temperatures are high. Thus, the background temperatures at the point of mixing may be lower than indicated in Figure 11, and this will introduce a slight error in the predictions.

The proposed releases will cause stream temperatures to cool by about 3°C compared to baseline during the incubation period for rainbow trout eggs (Fig. 11 of 2.7.2.4B-D). These post-project temperatures will result in a delay in emergence timing. Rearing temperatures are predicted to be reduced through the summer to early September, which may impact growth of age-0 fish. The primary risk of these changes is that juvenile fish may be smaller or in poorer condition prior to winter. Size and condition can be important factors contributing to survival over the winter period. These effects may be slightly offset by warmer temperatures compared to baseline in the late fall.

Recirculated water will have a major impact on overwintering rearing habitat in the streams. Although upper Fish Creek is described as having ephemeral flow (p. 6), previous trapping results found that large numbers of juvenile trout migrated from the creek to the lake in June and July 1997 (Taseko 2009, v5d009). This suggests that trout were able to find suitable rearing habitats for the winter, likely in beaver ponds, potentially supplied by groundwater. A more recent attempt to document overwinter use was unsuccessful, however, the sampling was limited in scale. Without knowledge of the groundwater sources, fish distribution is difficult to confirm by random sampling (Bradford et al. 2001).

As baseline flows recede in the fall, temperatures fall to 0°C and ice forms on the creeks. Flow augmentation is expected to increase winter temperatures (Figure 11) and that may prevent the formation of a surface ice layer on the creeks. Open water can exacerbate the formation of frazil and anchor ice, expose fish to predation risk, and create bio-energetically challenging conditions (see Brown et al. 2011). Although the mitigation flows are expected to cool downstream of the outlets, it is unclear where juvenile fish will be distributed in the stream relative to the ice-free or

covered sections of each stream. This is a particularly important uncertainty for upper Fish Creek, as fish production appears to be sustained by localized groundwater sources.

Finally, water temperatures in the spring months are predicted to be 2-3°C lower than baseline conditions (Figure 11). Juvenile growth can be rapid at this time of year (Bradford et al. 2001) as size at entry to the lake will likely confer a survival advantage (Post et al. 1999). The cooler recirculated water may impact growth and survival over the baseline condition.

In summary, there are a variety of risks to the stream fish populations associated with the change in the thermal regime resulting from augmentation flows, unless these risks can be minimized by ensuring the mitigation flow temperatures mimic baseline temperatures throughout the length of the tributary streams.

### **Eutrophication**

Pumping of nutrient-rich hypolimnetic water from Fish Lake into the inlet streams during summer for temperature control has the potential to stimulate primary productivity (periphyton). Orthophosphate concentrations in the inlet streams during the growing season was estimated at 8 µg/L (Taseko 2012, Vol. 2.7.2.4-BA, Table 2), much lower than the hypolimnetic concentrations in Fish Lake, which in July range from 77-205 µg/L (Fig. 2 below). Enhanced periphyton productivity may increase food production for fish, but may also shift periphyton species composition and contribute to the accumulation and deposition of organic matter in the stream channel, leading to the deterioration of stream bed conditions for spawning and egg incubation as noted above. Changes to the form and species of phytoplankton may also occur if there is strong nitrogen limitation resulting from the pumping of lake water (see Lake section below; Perrin and Richardson 1997). No analysis is provided of the effects of changes in nutrient chemistry however, sufficient information appears to be available to assess this risk.

### **Dissolved Oxygen**

The analysis of the end-of-pipe oxygen concentration suggests a high probability that levels will fall below acceptable values for much of the year. The winter period in Figure 15 is probably too short, as ice-related depletion is likely in December. The data in Figure 15 do not account for the ambient oxygen levels in the residual flows in the two tributary streams, which are unknown. Based on the production of juveniles from upper Fish Creek (Taseko 2009; v5d009), there must be sources of water in the upper Fish Creek channel that have sufficient oxygen to support fish. The addition of recirculated water with low oxygen concentration may cause conditions to deteriorate in the stream relative to the baseline.

Insufficient details are provided about the mitigation of low DO in the recirculation system. Given that the streams are short, and the short transit time of water, it may not be sufficient to rely on natural aeration to restore DO levels. Further, aeration during the winter months will require measures to avoid supercooling and the creation of frazil ice.

### **Changes in stream community structure and food production.**

The proposed isolation of the headwater areas of the two tributary streams and pumping lake water in to the streams is a very similar situation to a small impoundment (storage dam) and a regulated discharge. These changes are well described by the Serial Discontinuity Concept (Ward and Stanford 1983) and large body of supporting research. Some potential changes to the remaining stream include the elimination of particulate organic material, large woody debris, gravel and invertebrate drift exported from the headwaters to downstream habitats and the lake.

High flows in headwater streams mobilize stream gravels and maintain a supply of suitable size material to salmonid spawning areas from headwater areas. Isolation of headwaters by barriers

(e.g., dams) eliminates that recruitment. Consequently in most regulated systems the areas below the flow control structures tend to downcut and become gravel starved. The extent of gravel loss will depend on the magnitude of the peak flows, and their competency in mobilizing the bed. No analysis is provided on the potential for gravel loss although gravel replacement is listed as a mitigative measure in IR25i.

Pumped water will introduce zooplankton and fine particulate material from the lake to the stream, and these changes (as well as temperature and water quality changes) can lead to reduced or altered invertebrate communities downstream of the water outlets. The proposed mitigation measures for metals (nano filtration of recirculated water) will affect stream fish communities if nutrients, particulate matter and organisms are removed from the recirculated water.

These affects usually attenuate with distance from the point of flow regulation. It is not possible to predict whether these changes will alter the potential for the residual streams to produce juvenile rainbow trout, but they should be considered a risk factor given the short length of the residual tributary streams.

### **Fish Lake**

Lake productivity is governed by numerous abiotic and biotic factors, both internal and external to lake ecosystems (Wetzel 2001). Food web productivity is closely regulated by the availability and proportions of limiting nutrients (i.e. phosphorus and nitrogen) and light for autotrophic production, the efficiency of trophic energy transfers (i.e. algae→zooplankton or benthos→fish; governed by the abundance and species composition of prey items at each trophic level), and water quality parameters (i.e. temperature, pH, oxygen, contaminants) important to the persistence of fish species (Wetzel 2001, Kalff 2002). Other direct and indirect habitat limitations on fisheries productivity include factors that influence reproductive success and the survival of individuals and populations, such as the quantity of suitable spawning habitat (i.e. substrate, pore-water quality), dissolved oxygen availability (i.e. winterkills, hypoxia), sub-lethal and lethal contaminant levels in water and/or sediments, and predation rates (Hartman and Miles 2001).

### **Lake Recirculation, Limiting Nutrients, Lake Trophic Status, Lake Ecology and Fish Productivity**

The primary limiting nutrients to autotrophic productivity in lakes (and thus the basis for food web productivity for fish) are phosphorus (P) and nitrogen (N; Wetzel 2001; Kalff 2002). The Proponent has characterized Fish Lake as a chronically P-limited system in the EIS and previous submissions, applying an inter-lake fish biomass production model predicated upon an underlying assumption of primary production P-limitation (i.e. Plante and Downing 1993). The simplified characterization of Fish Lake, as a P-limited lake ecosystem throughout the growing season, has been disputed by DFO Science Branch during the 2009-2010 Prosperity Mine CEAA review process (documented in the testimony of D.T. Selbie in the CEAA hearing transcripts, Mainland, 2010), and the review of the draft and final EIS (DFO 2012a, 2012b). The predictions of future fisheries productivity (e.g. Plante and Downing 1993 model) and water quality are directly contingent upon the true seasonal nutrient limitation patterns in Fish Lake. Thus, the following discussion focuses on what is known of N and P dynamics in the system to better aid in understanding the validity of the models presented in the EIS, and the confidence in the future fisheries production estimates, should lake recirculation be permitted to support mine development.



N- vs. P-limitation in lakes is most commonly assessed through elemental stoichiometry, such as the comparison of total N (TN) to total P (TP) molar ratios ( $TN:TP_{molar}$ ; Guildford and Hecky 2000; Davies et al. 2004). Guildford and Hecky (2000) define autotrophic productivity as N-deficient at  $TN:TP_{molar} < 20$ , and P-deficient growth at  $TN:TP_{molar} > 50$ , with either N or P becoming deficient at ratios between 20 and 50. While  $TN:TP_{molar}$  is a broad measure of nutrient deficiency and limitation, the species of N and P available for primary producers (i.e. inorganic vs. organic and biologically sequestered vs. labile fractions) is of critical importance to the production of biomass at higher trophic levels. As such, the assessment of seasonally-resolved, biologically-available N and P concentrations in the water column, in relation to lake physical processes (i.e. thermal stratification), is important in understanding the effects of nutrient availability on primary production and ultimately food web and fisheries productivity.

The Proponent's 2012 EIS assessment of nutrient limitation in Fish Lake, supporting trophic status modeling, was based upon  $TN:TP$  molar stoichiometry from new sampling conducted in 2011. In contrast to previous sampling (1993-2006; Taseko 2009), the 2011 summer water chemistry samples were obtained by integrating samples throughout the water column. It is unclear why this approach was undertaken, as such sampling does not reflect the important seasonal ontogeny of spatial variations in nutrient availability within lakes. By contrast, existing data for the project, measured as discrete samples from specific depths, which more accurately reflect the spatial and temporal complexity of nutrient availability in Fish Lake, were not incorporated into this analysis. While a water column-integrated approach may approximate the overall N to P availability for the lake, annual limitation of food webs (and ultimately fisheries productivity) occurs during the ice-free, stratified period, within the biologically-active euphotic layer (area of light penetration stimulating primary productivity), and not throughout the water column (Wetzel 2001; Selbie et al. 2011).

In Fish Lake, the euphotic zone is shallow (due to organic staining and biological turbidity), and is mostly contained within the density-isolated epilimnion during the growing season (Shortreed and Morton 2000). As Fish Lake strongly stratifies for an extended period, surface waters exhibit a depletion of biologically-available inorganic N (i.e. nitrate, nitrite, ammonium) within the euphotic zone throughout the growing season (Figure 1A). While surface nitrate depletion occurs in BC lakes of varying trophic status (Shortreed et al. 2001; Selbie et al. 2011), the early onset, rate, and magnitude of  $NO_3$  depletion in Fish Lake is great (likely due to the abundance of biologically-available phosphorous throughout the water column (Figure 2A-C)), and can impact the seasonal development of edible phytoplankton and energy flow to higher trophic levels including rainbow trout.

Several lines of evidence indicate Fish Lake experiences N-deficient conditions for primary production. Moreover, the lake exhibits limnological characteristics that may exacerbate N-deficiencies should recirculation of hypolimnetic waters to the tributaries proceed (see subsequent text). The historical data provided in the original EIS (Taseko 2009) demonstrates that biologically-available inorganic nitrogen (e.g. nitrate,  $NO_3$ ) concentrations are at or below analytical detection limits throughout the water column across the entire growing season (i.e. May-October; Figure 1A-C). This pattern suggests N must be principally sequestered in biota or exist in N forms not readily available to food webs (i.e. dissolved organic N). While nitrification likely plays a role in fostering  $NO_3$  availability, as noted by Shortreed and Morton (2000) and the Proponent in IR #25, chlorophyll *a* levels below those expected given ambient phosphorus levels (see EIS Trophic State Models), and the presence and documented bloom formation of N-fixing cyanobacteria (e.g. *Aphanizomenon flos-aquae*, *Anabaena* spp., *Anabaenopsis* spp.) in summer and fall (Morton and Shortreed 2000; Taseko 2009 (Appendix 5-2-A)) suggest that Fish Lake food web currently experiences N-limitation during ecologically-important periods of the growing season. Shortreed and Morton (2000) highlight the potential ecosystem structural and

physico-chemical consequences of the possible stimulation of N-fixing cyanobacteria in Fish Lake:

"Low numbers of nitrogen-fixing and potentially bloom-forming cyanobacteria (*Anabaena*, *Aphanizomenon*, and *Anabaenopsis*) were present in Fish Lake. Of these species only *Anabaena* was observed in Wasp Lake, and none of the three were observed in Big Onion Lake samples. Since these species are normally most abundant in summer, the low numbers of these species at the time of sampling was not unexpected. However, the low N:P ratio and high P concentration in all 3 lakes suggests that summer blooms of these deleterious nitrogen-fixing cyanobacteria may occur, given appropriate physical conditions. If of sufficient magnitude, these blooms can lead to decreases in DO, and may be a hazard to both the lake's fish population and to animals using the lakes as a water source." (Shortreed and Morton 2000)

In contrast to seasonal N availability, biologically-available phosphorus (e.g. ortho-phosphate,  $\text{PO}_4$ ), deemed by the Proponent to be the food-web limiting nutrient, is abundantly available throughout the growing season and water column. While epilimnetic ortho-phosphate drawdown may occur during summer (Figure 2A),  $\text{PO}_4$  concentrations in the metalimnion and hypolimnion increase as the growing season progresses (Figure 2B,C), likely due to internal P loading from the sediments under annual hypolimnetic deoxygenation.

The data collected by the Proponent in their 2006 July and October sampling, which do not appear to have been used in the current water quality modeling, demonstrate TN:TP<sub>molar</sub> values ranging from 7.39 – 91.1 (data from Taseko 2009), indicative of water ranging from severe N- to severe P-deficiency for autotrophic production. Poor replication, however, and a high degree of variability in data from proximal sampling sites yields broad variability in the TN:TP<sub>molar</sub> values available to assess nutrient limitation (2006 data; Taseko 2009; Table 1). Such poor data replication and the failure to incorporate spatially-resolved nutrient availability in the 2012 EIS water quality modeling substantially reduce confidence in the Proponent's characterization of Fish Lake seasonal nutrient dynamics, and in the QA/QC of the water chemistry data needed to achieve the proposed future adaptive management using water chemistry indicators.



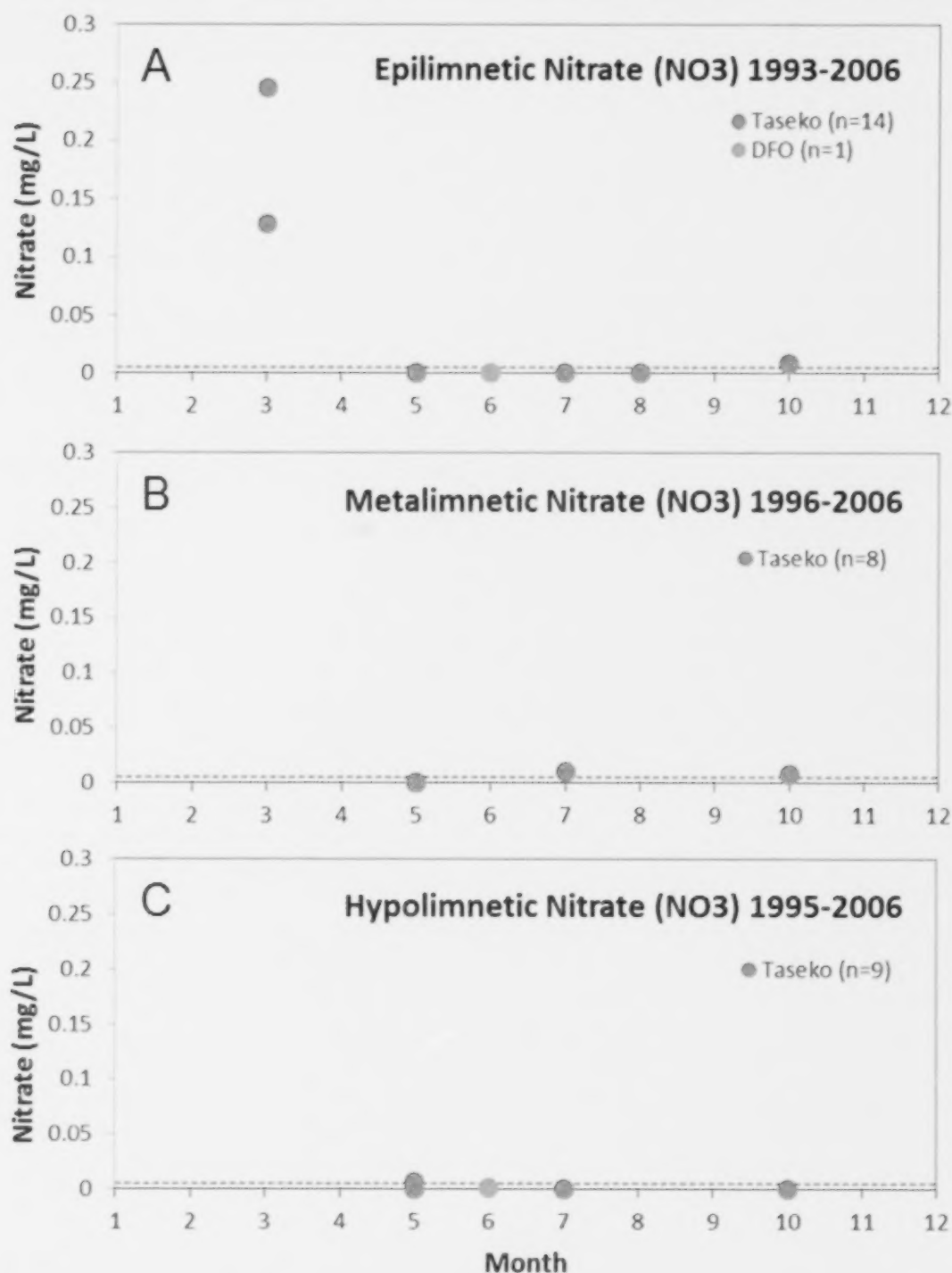


Figure 1: Seasonal development of nitrate (NO<sub>3</sub>) nitrogen concentrations in Fish Lake, BC in A) the epilimnion, B) the metalimnion, and C) the hypolimnion. Data from Taseko (2009, 2012) and Shortreed and Morton (2000). Red dashed line indicates analytical detection limit for NO<sub>3</sub>. Note total depletion of NO<sub>3</sub> throughout the growing season across all lake depth zones.

Table 1:  $TN:TP_{molar}$  assessment of nutrient limitation in Fish Lake from data collected by the Proponent (Taseko 2009)

Sampling Date	Sampler	TN (mg/L)	TP (mg/L)	Depth (m)	Station	$TN:TP_{molar}$	Note
23/05/2006	Taseko	0.79	0.0026	0.5	U1-1	671.90	Poor replication
		0.79	0.0212	0.5	U2-1	82.40	
23/05/2006	Taseko	0.79	0.0049	5	U1-2	356.52	Poor replication
		0.82	0.0293	5	U2-2	61.89	
23/05/2006	Taseko	1.32	0.0915	10	U1-3	31.90	Poor replication
		0.98	0.105	10	U2-3	*20.64	
04/07/2006	Taseko	0.84	0.0256	0.5	U1-1	72.56	Poor replication
		0.82	0.0199	0.5	U2-1	91.12	
04/07/2006	Taseko	0.79	0.0216	5	U1-2	80.88	
		0.81	0.0241	5	U2-2	74.32	
04/07/2006	Taseko	1.03	0.288	10	U1-3	*7.91	
		1.07	0.32	10	U2-3	*7.39	
01/10/2006	Taseko	0.795	0.0414	0.5	U1-1	42.46	Poor replication
		0.908	0.0844	0.5	U2-1	23.79	
01/10/2006	Taseko	1.26	0.0376	5	U1-2	74.10	Poor replication
		0.958	0.0431	5	U2-2	49.15	
01/10/2006		1.54	0.302	10	U1-3	*11.28	
		1.27	0.199	10	U1-3	*14.11	

\* indicates incidences of inferred N-deficiency ( $TN:TP_{molar} \leq 20$ ) for autotrophic production

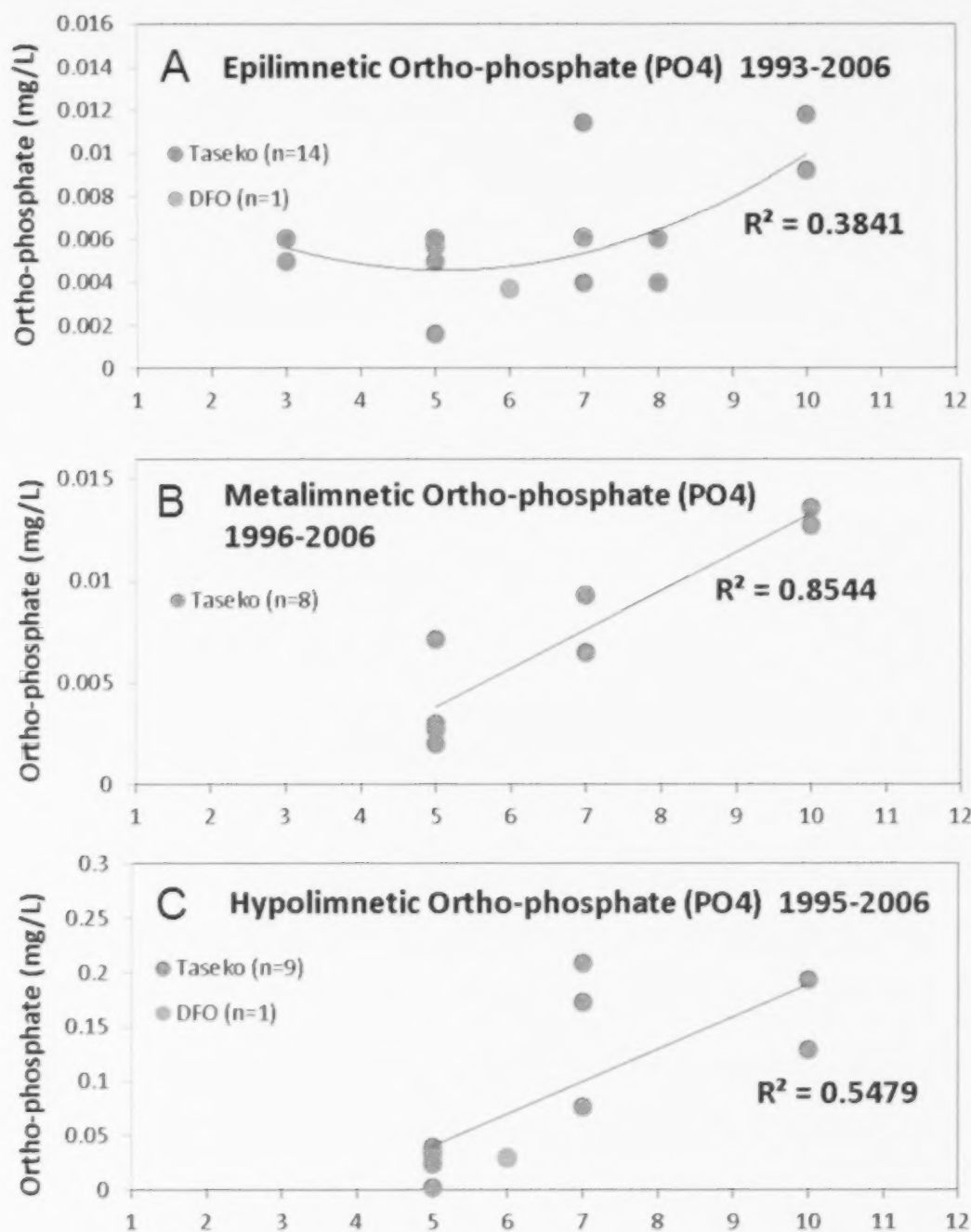


Figure 2: Seasonal development of ortho-phosphate (PO<sub>4</sub>) phosphorus concentrations in Fish Lake, BC in A) the epilimnion, B) the metalimnion, and C) the hypolimnion. Data from Taseko (2009, 2012) and Shortreed and Morton (2000). Note the increases in PO<sub>4</sub> in all strata throughout the growing season. A non-linear curve was fit to the epilimnetic data as winter/spring PO<sub>4</sub> data are available, and are expected to be elevated due to lake mixis.

Unfortunately there are no precedents for lake watershed recirculation to aid in understanding the potential effects of the New Prosperity Mine on the future food web and fisheries productivity in Fish Lake. Thus, water quality and fish production models that accurately characterize real food web limitations (N or P or both) throughout the growing season that quantify dynamic cycling of nutrients within the lake, and that yield sufficient predictive power, are essential to understand changes to the trophic ecology of Fish Lake under the proposed recirculation scenario. In IR #25, the Proponent indicates N-limitation is not expected, but goes on to say that any N-limitation will be alleviated by the biological response to N-limitation suggesting:

"Overall the process of recirculation would tend to favour the decrease in TN:TP, however we believe that this will be internally corrected in Fish Lake through the process of algal nitrification..."

While there is limited evidence for this *belief* in the 2012 EIS and subsequent IR's, and while nitrification does not principally occur via algae (but rather bacteria), a certain amount of bio-available N would likely be regenerated by nitrification of organic N, and partially via the "leakiness" of N-fixing cyanobacteria. The relatively low chlorophyll a concentrations in Fish Lake, given ambient phosphorus concentrations, however, do not indicate that these processes are currently adequate to offset seasonal N-limitation of primary production under the current lake state, and raise uncertainty about any "internal correction" under the proposed recirculation regime. Furthermore, the direct effects of N-limitation are not the sole impact on food webs. Should blooms of N-fixing cyanobacteria form and/or become more prevalent during the growing season, shading of more energetically-important edible phytoplankton can result, intensifying reductions in primary productivity and the biomass of edible phytoplankton and supported food web features (i.e. rainbow trout).

In the 2012 EIS (Fish Lake Mitigation Flow), the Proponent has proposed a multi-port, or multi-depth withdrawal system of recirculation which mixes cool hypolimnetic waters with warmer surface waters to ensure tributary incubation and rearing habitat are of optimal temperature for rainbow trout. While designed to regulate temperature, significant uncertainty exists in recirculation impacts on nutrient cycling and lake food webs supporting rainbow trout, as effects on lake nutrient cycling do not appear to have been accounted for. For instance, as noted in Table 1 (the Proponent's own sampling in 2006), hypolimnetic water in Fish Lake consistently exhibits TN:TP<sub>molar</sub> values indicative of severe N-deficiency for autotrophs. Recirculation of heavily P-laden and N-deficient hypolimnetic water to the epilimnion during summer poses the risk of reducing growing season N-availability for phytoplankton, and increases the probability of stimulating cyanobacterial blooms in Fish Lake with potentially deleterious structural and functional ecological consequences (see previous discussion). Moreover, as climate warming proceeds in this region (+2°C by 2050's, IR #18), the Proponent has indicated that the diversion of hypolimnetic water to the inflows is a mitigation strategy to combat warming stream temperatures and enhanced stratification. Such recirculation, however, would result in further delivery of N-deficient hypolimnetic water to the euphotic zone (IR #18). While the quantity of water that will need to be diverted is unclear, the effort has the potential to enhance N-deficiency in the euphotic zone of Fish Lake and potentially restructure food webs in ways that are not beneficial for rainbow trout productivity.

The quality of model outputs are contingent upon the quality and representativeness of their inputs. It is noted that the N species (i.e. TN, NO<sub>3</sub>) inputs to the water quality modeling (BATHTUB model) for in both the EIS and subsequently in IR#19 are held constant throughout the season. As such, predicted NO<sub>3</sub> (readily bio-available N fraction) in the EIS and TN predictions in IR#19 demonstrate exceedingly little seasonal variability. Moreover, NO<sub>3</sub> predictions for all mine phases and across all months predicted (see EIS) show no appreciable difference between epilimnetic and hypolimnetic NO<sub>3</sub> concentrations. The limited water



chemistry data presented by the Proponent, best captured in epilimnetic  $\text{NO}_3$  concentrations in Figure 1A, suggest that the lack of variability in predicted nutrient availability does not reflect real annual  $\text{NO}_3$  availability, which is likely critically-important to future food web productivity in Fish Lake. Coupled with the Proponent's own lack of confidence in nitrogen predictions from their modeling effort (see IR #19), the failure to adequately capture current seasonal nutrient (N) availability and accurately predict future nutrient variability, severely compromises confidence in the 2012 EIS predictions of future fish productivity in Fish Lake.

The preceding discussion highlights the importance of seasonal N-availability to food web productivity in Fish Lake and the potential uncertainties in future ecosystem dynamics associated with the proposed lake recirculation, yet the Proponent has predicted fish biomass using a model relating total phosphorus (TP) to fish biomass (Plante and Downing 1993). Lower than expected chlorophyll a concentrations relative to ambient TP concentrations in Fish Lake would suggest that perhaps a model using biological (i.e. phytoplankton) rather than chemical predictors would be more appropriate. In fact, the Plante and Downing (1993) model has a low predictive power ( $r^2 = 0.61$ ), and thus higher uncertainty in predictions, relative to models that use primary productivity (i.e. photosynthetic rates; PR) as a predictor of fish biomass such as Downing et al. (1990;  $r^2 = 0.79$ ), Plante and Downing (1993;  $r^2 = 0.68$ ), and Hume et al. (1996;  $r^2 = 0.86$ ). Given the tenure of such models in the literature, it is unclear why the Proponent, in the decades of data collection prior to the 2012 EIS, did not collect PR data to support their analyses.

Ultimately, it is unclear that the current limnological characterization of Fish Lake, and the fish biomass predictions based upon chronic food web P-limitation, are sufficiently accurate to confidently predict changes to Fish Lake. Moreover, as indicated by the Proponent, their own predictions of future N dynamics in Fish Lake are highly uncertain (see IR #19), and thus it is unclear how the recirculation of Fish Lake will impact N cycling within the watershed and lake (despite IR #19). Existing data indicate that this effort may enhance N-deficiencies in the euphotic zone of Fish Lake, which have the potential to reduce fish productivity as a result of reduced food web productivity and/or trophic restructuring.

### Mitigation Measures to Protect Aquatic Ecology of Fish Lake

The EIS indicates that mitigation measures will be undertaken for the protection of water quality to buffer any increases in lake phosphorus concentrations and impacts on Fish Lake productivity. In general, proposed mitigation methods to reduce phosphorus (i.e. hypolimnetic aeration, addition of alum to precipitate P), are accepted lake management practices for culturally-eutrophied lakes. The Proponent refers to "trigger or alert" phosphorus levels that, once exceeded, would trigger active mitigation. Based upon a reported range in baseline P conditions (15-42  $\mu\text{g/L}$  P), the Proponent calculated critical concentrations requiring mitigation to be in excess of 22-63  $\mu\text{g/L}$  (~ 50% greater than baseline P levels). The reported "trigger" range, however, was broad, and transcended multiple trophic state classifications. It was unclear what critical P concentration would precipitate mitigation actions, particularly as baseline conditions overlap with the predicted threshold range. The CEAA Panel requested further definition of thresholds in IR #49 to address these issues.

The Proponent has developed primary (i.e. TP, chlorophyll a, Secchi depth, dissolved oxygen) and secondary key indicators (i.e. metals, sulphates) of "lake health". The primary key indicators, aimed at detecting eutrophication have been set at Indication, Alert, and Action thresholds of 15%, 35%, 50% of baseline levels. While a more proactive approach has been offered in advance of the permitting phase, it is unclear what the sub-mitigation threshold effects of the progression of eutrophication will have on the lake ecosystem structure and functioning. For instance, are the ecological effects, and ultimate impacts on rainbow trout productivity, from

an elevation of TP from 35 µg/L to 52.5 µg/L benign? Additionally, the timelines for mitigation of eutrophication (i.e. hypolimnetic aeration, hypolimnetic oxygenation) are presented as six months to one year. If eutrophication rapidly enhances the depletion of hypolimnetic or under-ice oxygen, are these timelines realistic in preventing winter-kill of the rainbow trout population in Fish Lake? Moreover, if such conditions stimulate rapid internal loading, the rate of change in TP concentrations and food web effects could be faster than predicted. Ultimately, it is unclear that the adaptive management plan offered by the Proponent is of sufficient rapidity to account for a state-shift in eutrophication caused by a non-linear internal loading response.

In IR #49, novel mitigation measures for anticipated metals contamination of water are proposed, which include nano-filtration (NF) of a large volume of lake water at extremely high rates (~8000L/min). Nano filtration (NF) of water is intended to remove multi-valent ions, but presumably particulate matter, such as suspended organic detritus and seston would be removed as well. This novel approach raises questions about the impact of lake-water filtration on planktonic organisms as well as detrital and trophic recycling. If N recycling in the water column is important to N availability, as has been indicated by the Proponent (i.e. IR #19, #25), continuous filtration of the lake water may impact N availability in Fish Lake further. As there is no discussion of the interactions between water filtering and nutrient availability, lake water filtration raises considerable uncertainty for future nutrient dynamics in Fish Lake.

Similarly, contamination of lake sediments is proposed to be mitigated by way of nano-filtration (IR #49). Few logistical details are offered for this approach. It is unclear how sediment would be removed to be filtered, and what would happen to the sediment following filtration. Additionally, the area over which this technique would be applied is not known. Further detail is required to assess the potential impacts of sediment filtration on substrate-associated fauna, lake turbidity, and sediment-sequestered nutrient and contaminant remobilization, as such changes have the potential to have novel and deleterious impacts on fish habitat.

The mitigation, or at least retardation of eutrophication in Fish Lake may be achievable given the proposed mitigation techniques for reducing nutrients and enhancing oxygen. Large uncertainties exist, however, as to the sub-mitigation habitat and fishery productivity effects of eutrophication in Fish Lake, and whether remediation timelines (i.e. months to years) are commensurate with persistence of a rainbow trout population (i.e. enhanced oxygen depletion and winter kill prior to successful mitigation). Successful adaptive management would be directly contingent upon monitoring efforts of sufficient duration, extent, and quality.

Novel mitigation efforts introduced in IR #49 to address metal contamination in water and sediment present clear uncertainties in their interactive effects with plankton and nutrient recycling as well as physical impacts on benthos, water turbidity and sediment-water nutrient fluxes.

## Conclusions

The 2012 EIS builds upon a former CEAA project submission that was deemed by a federal review panel and the Government of Canada to have significant adverse environmental affects, and was not approved for development. The New Prosperity Mine configuration was modified from the original plan to prevent the immediate destruction of Fish Lake to create a tailings pond. In the New Prosperity Mine configuration, the Fish Lake watershed would be extensively altered, requiring intensive engineering efforts to maintain flows and lake levels. While Fish Lake itself would not be directly destroyed, as noted by the Proponent in the 2012 EIS, the lake is predicted to experience eutrophication and contamination with development of the mine.

### **Tributary streams**

To meet the goal of a viable self-sustaining rainbow trout population in the Fish Lake ecosystem the two tributary streams must provide sufficiently productive spawning and juvenile rearing habitats to support the lake population.

This review has identified a number of risk factors associated with the isolation of the headwaters and recirculation of flow into the remaining segments of the spawning and rearing tributaries of Fish Lake. Many of these factors are very similar to those observed for water regulation and diversion projects. The need for mitigation of some of these effects (nutrients, temperature, DO) has been identified in the EIS, but few details are provided. While much of the focus of the Proponent's mitigative measures and adaptive management program is on Fish Lake, the goal of maintaining a viable ecosystem for the Fish Lake rainbow trout population cannot be achieved unless a similar program is in place for the tributary streams.

IR25*i* and *j* provide some details regarding a monitoring and adaptive management plan for the Fish Lake ecosystem and a list of potential monitoring indicators and mitigative measures for the tributary streams is provided. However, a number of the risks identified in this document are not addressed, and there is very little detail in the various IR and SIR documents on which to judge the merits of an adaptive management approach for the tributary streams.

### **Fish Lake**

The recirculation of the Fish Lake watershed to support mine development will impose several changes on the aquatic ecology of Fish Lake. In general, eutrophication of the system is expected, and would modify structural and functional aspects of the ecosystem that support the rainbow trout monoculture.

The Proponent has attempted to predict the future water quality and fisheries production in Fish Lake under the proposed recirculation regime. As noted in DFO (2012a,b) and in this SSR, concern exists that current and future impacts of N-deficits on ecosystem productivity may be more substantial than has been characterized by the Proponent in the 2012 EIS and subsequent IR's. It is concluded that the recirculation regime may exacerbate existing N-limitations of food web production in Fish Lake, by recirculating N-deficient hypolimnetic waters to the inlets to maintain flows in spawning and rearing lotic habitats, and to combat the anticipated impacts of climate change on both lotic and lentic habitats in the manipulated watershed. Existing water quality model inputs likely do not capture real seasonal variability in N-availability in Fish Lake throughout the growing season, necessarily dampening variability in future water chemistry predictions. As predictions of future fish biomass in Fish Lake are predicated upon using a model assuming P-limitation (i.e. Plante and Downing 1993), the future dynamics of N in the system are critically important to the future abundance and biomass of rainbow trout in Fish Lake. At present, significant uncertainty exists in the predictions of fisheries productivity.

Several instances of poor data replication are noted in the historical data (Taseko 2009), which demonstrate a lack of representativeness in water chemistry sampling by the Proponent, and compromise assessment of the spatial and temporal complexities of nutrient limitation within the lake (see Table 1). These QA/QC issues raise significant concern and uncertainty regarding the likelihood that adequate monitoring will be undertaken to effectively implement the proposed adaptive management plan (AMP) to mitigate unexpected ecosystem changes, as the AMP is based largely upon key water quality indicators. Furthermore, the ecological impacts of sub-Action Threshold changes (i.e. at Indication and Alert levels) on habitat quality and food web and fisheries productivity are not known, and raise uncertainty in the impacts of eutrophication on the rainbow trout population. Additionally, in IR #25, the Proponent describes novel filtration

approaches to metals contamination of water and sediment. As noted, no assessment is provided on the potential impacts of these approaches on water quality, despite potentially important influences on habitat quality for rainbow trout (i.e. nutrient cycling, turbidity, filtration of seston).

Ultimately, as noted, there are a number of risks associated with the proposed recirculation that have not been addressed in the 2012 EIS or subsequent IR's that raise substantial uncertainty in the future habitat and fisheries productivity of Fish Lake under mine development, and the ability of the lake system to support a self-sustaining rainbow trout population.

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